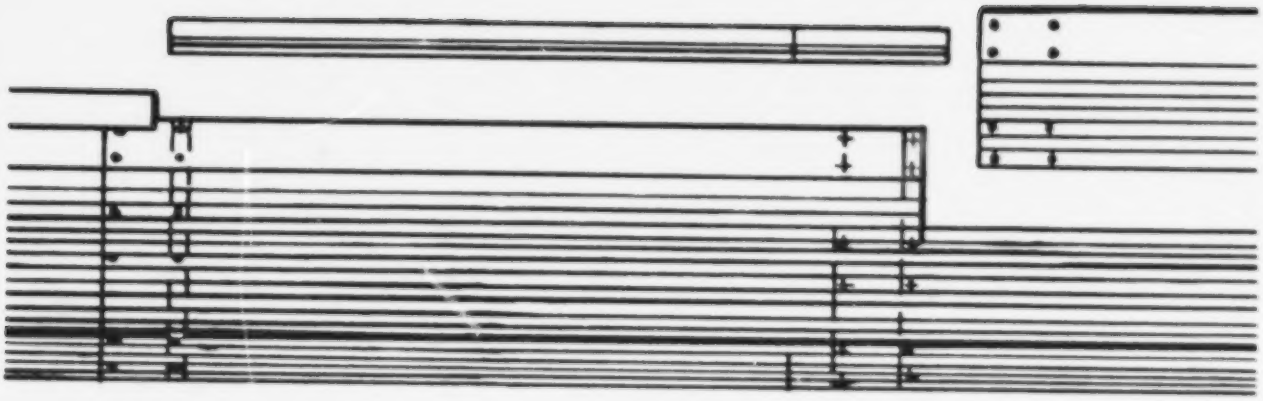
RE-85-01

IBC Barrier Monitoring



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Ministry of
Transportation and
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RE-85-01

IBC Barrier Monitoring

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Abstract:

A new design of median barrier developed by the International Barrier Corp. (IBC) was installed on a section of freeway and its performance monitored for one year. Aspects monitored included construction, maintenance operations, and product durability. Also, test coupons were laboratory tested to determine resistance to corrosion.

The key performance area of safety was assessed, in part, through the use of video monitoring and analysis of accident records. Although the IBC barrier performed as expected in this area, the data were not sufficient to provide conclusive results. A separate report on the IBC barrier system provides an evaluation of the design in terms of its cost-effectiveness, compared to other median barrier systems.

Key Words: Median barriers

Comments: One of two reports documenting the IBC demonstration on Hwy 400, near Toronto.

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EXECUTIVE SUMMARY

Introduction

Various offices of the Ministry contributed resources and expertise to report on aspects of a trial installation of the IBC barrier, built on Highway 400, north of Highway 401. The observation period was one year.

The sections of this report were submitted as independent parts and cover aspects of IBC performance in the field during the observation period.

Experimental Site and the IBC Barrier System

The experimental site chosen was on Highway 400, between Finch and Highway 401, where the IBC barrier system was used to replace an existing box beam installation. The site was selected, in part, because of its central location with regard to public exposure, but space restrictions resulted in somewhat narrow shoulders in the median.

The IBC design comprises two steel walls about 1 m high, connected by diaphragms. It stands directly on the ground and is filled with massive granular material. In terms of design features, the IBC barrier offers a high level of safety performance by gently redirecting and containing not just cars but also heavier vehicles such as trucks.

The installation cost of the IBC barrier as built on HWY 400 was $183.70 per metre. Annual operating and maintenance cost for the installation, based on one year of monitoring, was $3.10 per metre, per year, excepting retrofit items. This does not include the costs of repairing scratches or other damage caused by minor hits (reported in Section 4, "Video Monitoring and On-Site Observations").

Collision Data

Recorded data on vehicle collisions with the previous box beam barrier for three years prior to installation of the IBC barrier were compared with the collisions recorded during the one year of IBC barrier exposure. The rates (per year, per MV-km) of major collisions, property damage and injuries where somewhat in favour of IBC, although the data were not sufficient to draw conclusions with certainty. For example, no barrier collisions recorded during the study period involved a heavy truck. Therefore the anticipated better performance of the IBC barrier with regard to containment of heavy trucks was not utilized.

Video Monitoring and On-Site Observations

Part of the test section was monitored by video camera. The video tapes showed that, although it was located relatively close to the edge of the travelled lane, the IBC barrier apparently had no influence on vehicle speed or positioning in the lane. The tapes also permitted accident timing sequences and other features to be studied after the event, and traffic flow around stalled vehicles could be observed.

Other observations made by visual on-site inspection revealed traces of about 100 unrecorded minor collisions on either side of the barrier. These had resulted in some damage to the barrier coating and some indentations of metal. Minor hits of this nature will likely have some adverse effects on life-span and future maintenance costs.

Construction Report

No difficulties were encountered during construction, except some minor problems due to the workers' unfamiliarity with IBC installation. The IBC barrier was originally designed as a temporary installation for race tracks, easy to install and remove. A covering lid, extra vinyl coating and galvanizing were added to make it a permanent installation.

Laboratory Testing of PEAA, PVC Coatings

Laboratory tests of coatings as applied to the test installation showed results to be satisfactory, with some minor problems at the edges of the coatings.

Maintenance Operations Report

For IBC maintenance operations, special equipment is needed beyond the usual maintenance inventory. This includes a vacuum sewer cleaner to remove granular fill from the barrier before repair work, and a "stone slinger" to refill after repair.

Due to the narrowness of the median at the test installation site, repair operations and cleaning of catchbasins required the closure of both lanes adjacent to the barrier, affecting traffic flow on both sides.

Compared to other steel barriers and to concrete, the IBC exhibits less self-cleaning of the steel profiles. Although maintenance costs were higher than for other barriers, there were no major difficulties in maintenance of the IBC system during the 12-month observation period.

No repairs were carried out by MTC to remove the traces of unrecorded minor collisions. However, the accumulation of such hits may cause some additional costs in the future.

Conclusions

The IBC barrier system has a level of safety performance as high or higher than any other standard MTC barrier. It is somewhat superior to the standard N.J.-type concrete barrier in its ability to redirect compact and sub-compact cars hitting at small and moderate angles (< 15°). It is also somewhat better at containing and redirecting heavy trucks, although the increased utility of these improved features is uncertain and could not be verified by the field experiment.

On the other hand, in the Ontario milieu, the cost of the IBC system seems to be higher than other systems, especially the standard concrete barrier. In particular, the IBC system requires more effort in maintenance as minor collisions resulted in some damage of panels. By comparison, concrete barriers subject to similar minor collisions suffer only tire marks.

1/ INTRODUCTION

It is generally recognized that, in the past, highway safety barriers have been designed primarily to contain and gently redirect standard sized cars. In the last few years, however, a number of new designs have been developed to cater to a wider range of vehicles, from buses and heavy trucks down to cars. These new designs include improvements to concrete barriers and steel beam guiderail systems and a new concept, the IBC barrier, devised by the International Barrier Corporation, an Ontario based company.

Following successful demonstration of the IBC barrier in crash tests*, the Ontario Ministry of Transportation and Communications (MTC) decided upon a trial installation in the median of a major freeway. The purpose was to assess the capability and utility of the IBC barrier under actual service conditions in Ontario.

A study team was assembled from various offices of the Ministry to monitor the IBC barrier in terms of accident experience, traffic and operational characteristics, design, construction and maintenance factors and other performance features, as observed in the first 12 months after the barrier entered service in November, 1984.

The study team members contributed various sections of this report while the co-ordination of the report was undertaken by Highway Operating Systems Section (F. Jung, Senior Research Engineer), Research and Development Branch. The result is a symposium of various reports on aspects of IBC system performance through one year. Specific contributions are as follows.

Section 2 of this report contains a brief description of the experimental site and the assembly of the IBC barrier installation, together with an outline of its performance features.

---

* Carried out by Calspan Advanced Technology Center in Buffalo, Motor Industry Research Association (MIRA), and Transport Canada Motor Vehicle Centre (Reported by International Barrier Corporation).

Section 3 reports on an investigation of "before" and "after" accident experience involving the median barrier. Three years of box beam performance on the same site are compared with one year accidents and performance of the IBC. These comparisons are based on conventional accident reports.

Section 4 reports on the video monitoring and on-site observations, including a counting of minor collisions beyond the recorded accidents.

Section 5 provides information on the construction of the IBC barrier on Hwy 400.

Section 6 contains data on laboratory tests of the PEAA/PCC coatings as applied in the field.

Section 7 is a maintenance operations report on one year's field experience with the IBC installation, including an estimate of cost.

2/ EXPERIMENTAL SITE AND THE IBC BARRIER SYSTEM

2.1/ Experimental Site

The IBC barrier (type MK-VII of the International Barrier Corporation) was installed on a 3.75 km section of Hwy 400, north from Hwy 401 to a point north of Finch Avenue, see layout in Figure 1. The barrier replaced an earlier box beam installation, and is located in the centre of a narrow paved median which is about 3 m (10 ft) wide for most of its length.

The site was chosen because of its central location, visibility to the public, and the possibility of widening the highway beyond the present total of 6 lanes in the not-too-distant future. Also, the Sheppard Avenue overpass provides a convenient location for video surveillance. The selected site is characterized by a high volume of traffic.

The IBC barrier replaced a box beam barrier in the same width of median between existing roadways. As a result of the IBC barrier's additional width, shoulder space was reduced to about 1 m -- considerably less than would have been desirable for a new installation. This situation may have resulted in an increased number of minor hits, most of which were not recorded as accidents.

In the first year of installation, there were about 115 minor hits on each side of the barrier, involving damage to barrier sheet metal or coating ranging from traces of paint damage up to serious denting. This amounts to a minor collision rate of 30 per year per km. (Traffic volumes during this period are presented in Section 5.) The number of hits could be expected to be lower with wider shoulders.

The IBC barrier is galvanized and vinyl-coated on the outside in a light grey colour. Under the standard illumination of this section there is adequate visual conspicuity at night. An additional advantage is that the solid, high IBC barrier cuts off all headlight glare at night from opposing traffic. This headlight glare was present with the previous box beam barrier and it had the effect of reducing the visibility of critical objects on the road surface.

An overview of the installed IBC barrier is shown in Figure 2.

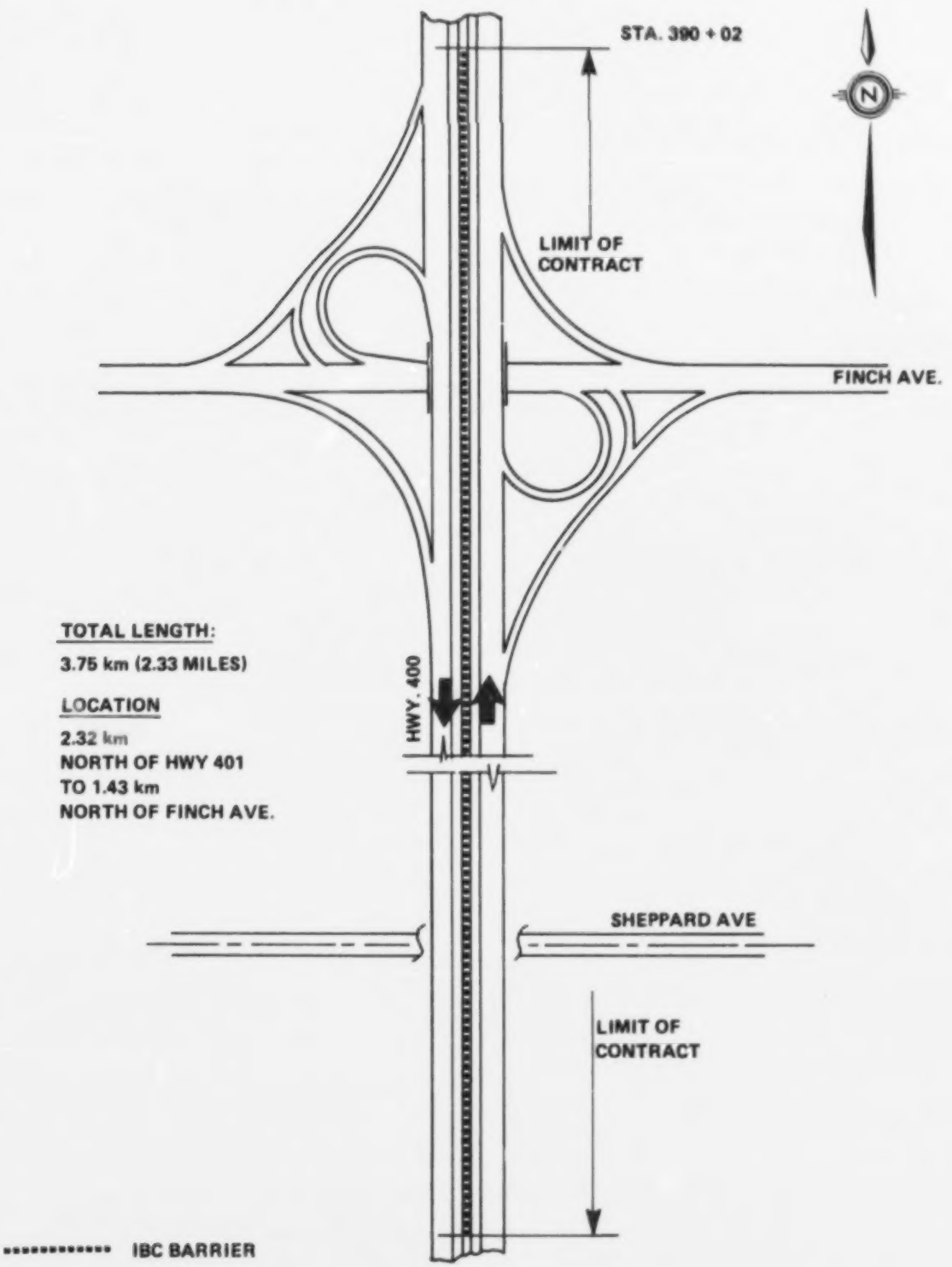

Figure 1/ Plan of Hwy 400 with IBC Barrier

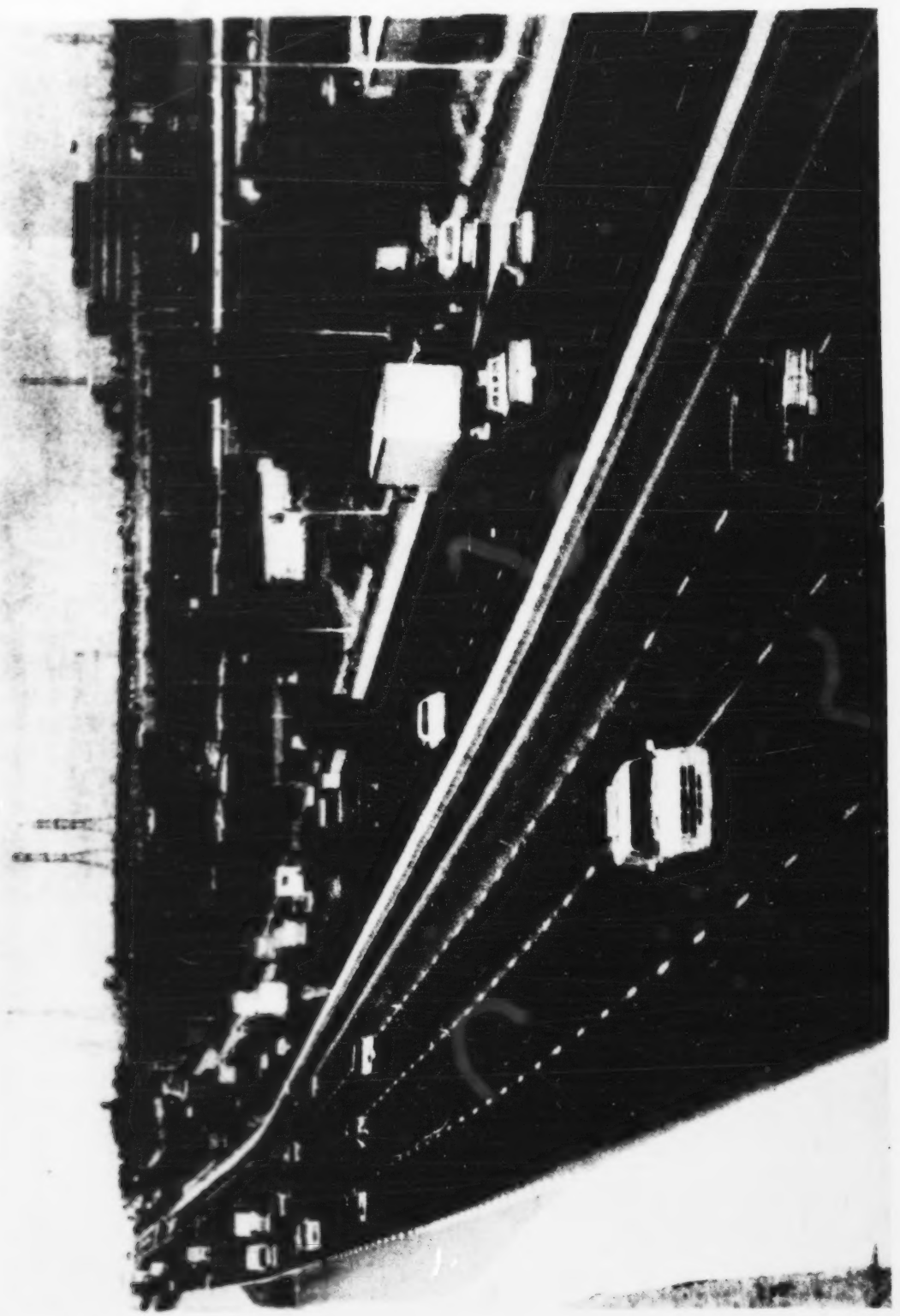

Figure 2/ Overview of Installed IBC Barrier

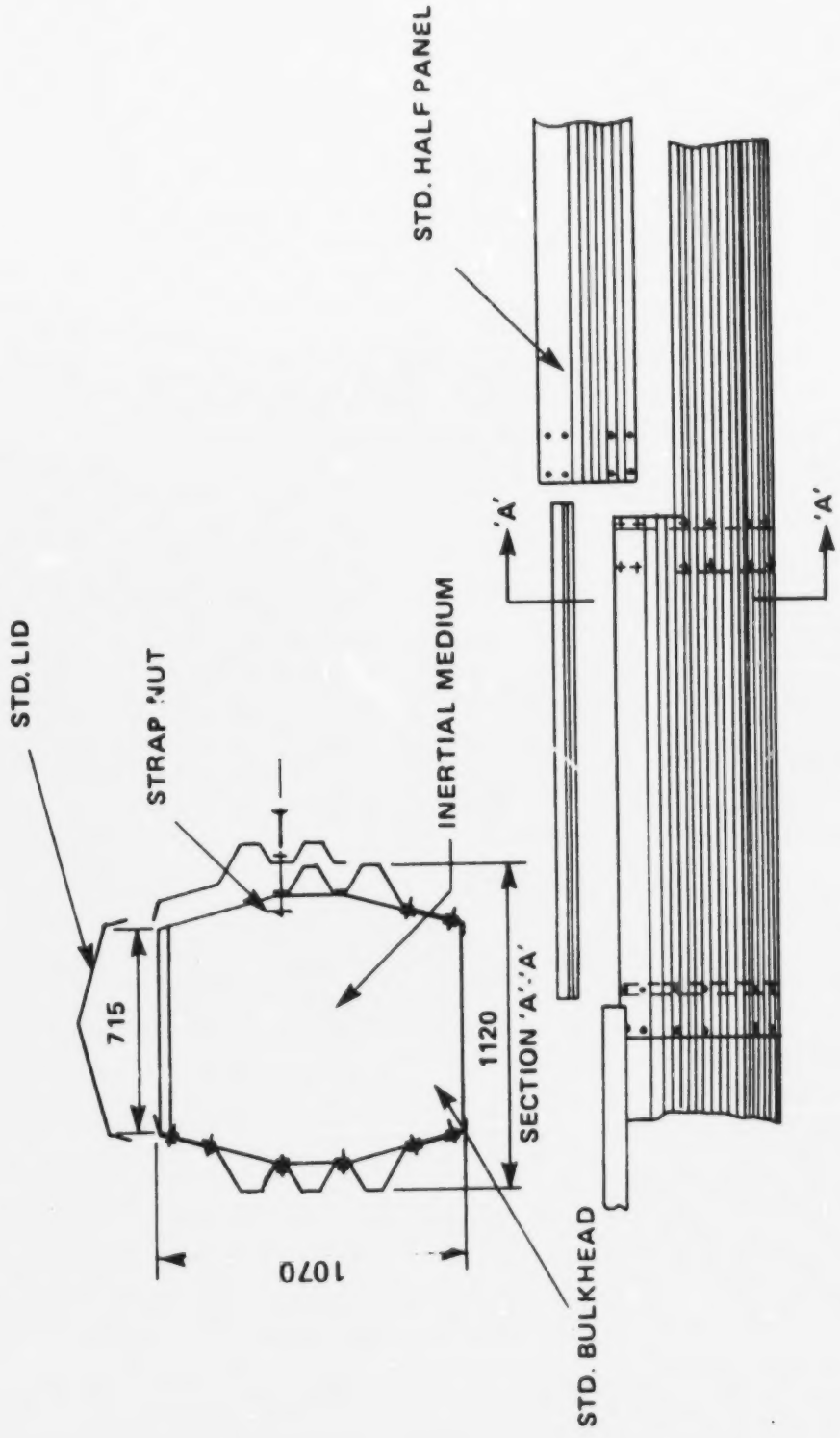

Figure 3/ Assembly of IBC Barrier (Mark VII)

2.2/ IBC Barrier Description

The IBC barrier as shown in Figure 3 is a steel structure of 3 mm cold-formed profiles, supported by an interior diaphragm at regular intervals (3.21 m). The panel material is made to ASTM A446, grade A, steel specifications, hot-dip galvanized with a G90 coating. The interior is filled with sand or gravel and covered by a lid. For increased corrosion protection the steel panels may be vinyl-coated on top of the zinc galvanizing. The barrier is free-standing on the ground.

Functionally, the IBC barrier is designed to:

1/ redirect all vehicles impacting at about normal travel speed (<100 km/h) and normal impact angles up to about 15° with moderate lateral and longitudinal compartment deceleration (6 G) and very small roll angles;

2/ contain virtually* all impacting vehicles, even heavy trucks, hitting the barrier at combinations of speed and angle as high as 100 km/h, and 25°, respectively. This is beyond the usual requirements for median barriers.

Attainment of these functional design intentions seem to be supported by tests reported by IBC involving vehicles ranging from small cars to buses and trucks, although some actual deceleration measurements are missing in the pertinent reports.

In particular, a vehicle hitting the barrier at about 15° or less, depending on mass and speed, will noticeably or severely indent the protruding ribs of the profile, thus cushioning the left-front corner impact. The vehicle is redirected with moderate lateral deceleration of the compartment. The roll angle exhibited by small and medium vehicles such as cars, vans and pick-up trucks is hardly noticeable. Heavier vehicles may exhibit some moderate roll angle which is relatively harmless to passengers. However, impacts at blunt angles (>25°) may be very hazardous or even fatal -- although, because it is deformable, the IBC barrier may be more forgiving in such circumstances than a concrete barrier.

---

* Note -- the term "virtually" as used here assumes that the combination of highest impact speed, highest impact angle and highest gross weight is unlikely.

3/ ACCIDENT COLLISION STUDY

3.1/ Accident Information*

This chapter outlines the information obtained from collision reports prepared by OPP officers to describe accident events which took place in the vicinity of the IBC barrier on Hwy 400 between November 1, 1983, and October 31, 1984.

In addition, collision experience for the same portion of Hwy 400 for the years spanning 1980 to 1982 was reviewed. During this period, a box beam barrier was in place. Table 1 presents many of the details which were recorded to address the operational characteristics of both box beam and IBC barriers.

In conjunction with the collision analysis, traffic volumes were collected in 1984 by Central Region Traffic Section to ensure all accident rates calculated were accurate and current. This evaluation includes comparisons with adjacent sections of Hwy 400 to analyse past and existing service levels against those observed on video tapes (in an earlier study by TM&EO).

The video tapes were recorded to show before and after traffic operations on Hwy 400 north of Sheppard Avenue. More specifically, they were used to address issues such as driver comfort, lane occupancy, and vehicle reactions to median barrier impacts. The results are contained in the text which follows, as are the observations and recommendations of the author.

3.1.1/ Observations

3.1.1.1/ Using Table 1

1/ It was established that the number of collisions within the study area was 7% lower in 1983-84 than the annual average number of collisions recorded in the three previous years 1980 to 1982. It should be noted that 1981 collision experience was extremely high compared to the remaining three years of study and consequently collision experience for the study period 1983-84 should be considered normal.

---

* This section (3.1) of the report was compiled by Mr T.A. Mitchell, Traffic Management and Engineering.

Table 1/ Median Barrier Collisions, 1980-82 and November 1, 1983 to October 31, 1984, Hwy 400, IBC Evaluation

	Box Beam			IBC
	1980	1981	1982	1983-1984
Total collisions in study area	113	160	107	118
Total rear end collisions in study area	49	71	29	42
Total accidents involving median barrier	32	41	56	34
Total barrier hits - primary impact	18	32	47	24
Total barrier hits - secondary impact	16	11	11	10
-Total collisions where vehicles returned to driving lanes after barrier impact	6	7	4	9
-Total collisions after barrier impact	3	5	1	5
Total rollover accidents after barrier impact	-	-	-	-
Total penetrations of barrier	1	-	-	-
Total # of persons killed in barrier collisions	-	1 *	-	1 *
Total # of persons injured in barrier collisions	21	19	33	11
Total # of PDO collisions with barrier	19	27	40	26
Estimated property damage	$93 500	$105 245	$147 475	$101 505
Total collisions in study area involving trucks	28	36	25	15
Total collisions where trucks contacted barrier	1	1	5	-

*In both instances, the barriers were not responsible for the injuries that caused death.

2/ The number of rear-end collisions recorded during the 1983-84 study period was 15% below the average of the first three years in the study area. As mentioned, 1981 was extremely high and therefore this latest year of the study is not significantly at variance with normal accident experience. It should also be noted that the occurrence of rear-end collisions involving disabled vehicles in the passing lane is significant and accounted for 9 of 42 rear-end mishaps in the 1983-84 study period. Only 7 such collisions were recorded between 1980 and 1982.

3/ The number of reported median barrier collisions for the 12 month study period of 1983-84 was 21% below the three year average recorded in 1980-82.

4/ The reduction in the number of primary impacts with the median barrier was consistent with the reduction in overall collision experience. It was recorded lower than the previous three years' average by 26%.

5/ Similarly, median barrier collisions which resulted from collisions occurring elsewhere on the roadway dropped by 21% from the previous three year average.

6/ The number of incidents where a vehicle struck the barrier system and clearly returned to the driving lanes where additional conflicts might occur increased in the 1983-84 study period by 59% over the previous three year average. This observation excludes those incidents where vehicles contacted the barrier, bounced off and then returned to the barrier after being deflected less than the full width of the shoulder (i.e., vehicle must clearly be entirely within a driving lane). This approach was adopted when it was observed that almost all median barrier collisions in the 1983-84 study period resulted in the final position of the vehicle being at least partially within the passing lane. This encroachment problem was not as evident with the evaluation period of 1980-82.

7/ The number of incidents involving vehicles which previously struck the median barrier and returned into the driving lanes to collide

with other vehicles or fixed objects increased notably in the 1983-84 portion of our study. Our statistics indicate an increase of 67%.

8/ No rollover accidents were recorded within the study area. However, provincial reviews indicate there is some evidence of this occurrence elsewhere involving a variety of barrier systems used both in the median and on the shoulder. This type of accident is under investigation.

9/ Within the study periods only one penetration was recorded. It did not involve a heavy truck but did occur on the box beam system. In terms of statistical representation a decrease of one may not be considered as significant.

10/ Fatalities, fortunately, were confined to two events. One event involved the IBC barrier system; the other involved the box beam system. In both cases contact with the barrier resulted after initial impacts with other vehicles.

11/ The number of persons injured during the 1983-84 evaluation period were significantly reduced when compared with the previous three year average. Our figures indicate the decrease to be 55%.

12/ Consistent with the reduction in personal injury accidents in 1983-84 is the subsequent increase in "property damage only" accidents. Obviously, if overall accident experience remained constant and personal injury accidents represented a smaller portion of the overall experience then Property Damage Only accidents must have increased proportionately.

13/ Annual property damage estimates indicate the 1983-84 property damage recorded was 12% lower than the average annual estimate for the first three years of the study.

14/ The study period of 1983-84 recorded 49% fewer accidents involving heavy trucks. It should be pointed out this observation excludes pick-up trucks or vans of relatively small mass. Since it is contended that large, heavy trucks involved in collisions are more

likely to test the dynamics of the barrier systems severely (possibly resulting in death, personal injuries and significant property damage) the interaction of such vehicles with the barrier system should be closely monitored.

It should be pointed out, however, that our studies of heavy vehicles indicate their involvement in median barrier collisions is confined on the average to only 0.5% of all collisions. Further, the heavy trucks involved in accidents which also become involved in median barrier collisions represent only 4% of all accidents involving heavy trucks.

Based on the above information it is not surprising that there were no records of a heavy truck striking the IBC barrier system during the brief 12-month study period. However, seven truck contacts were recorded in a three year period on the box beam system, five of them occurred in 1982 alone. There does not appear to be any explanation for the 1982 experience except that three of these incidents occurred when road surface conditions were icy or snow covered.

3.1.1.2/ Using Tables 2 to 5

1/ In 1980, six median barrier collisions occurred which involved vehicles that returned to the driving lanes after impact with the median barrier. These were spread over a period from April to November with the peak month being September.

2/ In 1981, seven incidents were recorded where vehicles which struck the median barrier returned to the driving lanes. Four of these incidents occurred between December and February.

3/ In 1982, as shown in Table 4, there were four incidents where vehicles returned to the driving lanes after barrier impact. All of these mishaps occurred between January and April.

4/ Table 5 shows nine occurrences where vehicles returned to the driving lanes after barrier impact. Eight of these occurred during cold weather months (December 1983 to March 1984).

Table 2/ 1980 Median Barrier Collisions Distribution by Month, Hwy 400, IBC Evaluation

	Total Number	No. of Collisions where Vehicle Returned to Driving Lanes	Subsequent Collisions
January	1	0	0
February	5	0	0
March	0	0	0
April	4	1	0
May	1	1	1
June	2	1	0
July	2	0	0
August	1	0	0
September	4	2	1
October	5	0	0
November	5	1	1
December	2	0	0
Totals	32	6	3

Table 3/ 1981 Median Barrier Collisions Distribution by Month, Hwy 400, IBC Evaluation

	Total Number	No. of Collisions where Vehicle Returned to Driving Lanes	Subsequent Collisions
January	8	1	1
February	3	2	1
March	3	0	0
April	1	0	0
May	5	1	1
June	6	1	1
July	1	0	0
August	3	0	0
September	5	1	1
October	0	0	0
November	0	0	0
December	6	1	0
Totals	41	7	5

Table 4/ 1982 Median Barrier Collisions Distribution by Month, Hwy 400, IBC Evaluation

	Total Number	No. of Collisions where Vehicle Returned to Driving Lanes	Subsequent Collisions
January	17	2	1
February	2	0	0
March	6	1	0
April	4	1	0
May	2	0	0
June	6	0	0
July	1	0	0
August	3	0	0
September	2	0	0
October	2	0	0
November	3	0	0
December	8	0	0
Totals	56	4	1

Table 5/ Median Barrier Collisions Distribution by Month, November 1, 1983, to October 31, 1984, Hwy 400, IBC Evaluation

	Total Number	No. of Collisions where Vehicle Returned to Driving Lanes	Subsequent Collisions
January	5	2	0
February	5	1	1
March	5	4	3
April	1	0	0
May	2	0	0
June	5	0	0
July	1	1	0
August	2	0	0
September	0	0	0
October	1	0	0
November	1	0	0
December	6	1	1
Totals	34	9	5

3.1.1.3/ Using Video Tape Observations and On-Site Reviews

1/ Vehicle position in the passing lane averaged 0.75 m from the edge of the yellow edge line when the box beam was in place and was not changed with the IBC system installed.

2/ Occupancy of the passing lane in 1982 represented approximately 25% of the northbound traffic during a sample peak period and 30% southbound. The lanes were not congested and operated at a reasonable level of service.

3/ Occupancy of passing lane in the 83-84 study period changed modestly to 26% northbound and 27% southbound under much heavier traffic volumes and resultant congested periods.

4/ Debris and some snow seemed to collect at the base of the IBC barrier in modest amounts (as determined by visual observation) causing traffic to divert on occasion to avoid contact with pieces of tires, hub caps or other dangerous materials.

5/ Contact with the IBC barrier was evident from numerous blemishes, scratches etc., viewed on the new system. Police reports were not available for all of these contacts.

3.1.1.4/ Using Volume Data Collected by Central Region Traffic

The following observations were noted:

1/ Traffic volumes since 1982 have increased 27.3% from 91 500 to a recorded volume of 116 480 in 1984 for that portion of Hwy 400 between Hwy 401 and Finch Avenue. North of Finch Avenue to Hwy 7, volumes increased 28.3% from 58 250 in 1982 to a recorded volume of 74 738 in 1983. Table 6 shows the traffic volumes for the sections concerned for each of the study years. It should be noted that the volume data on the section of Hwy 400 south between Hwy 7 and Rutherford Road is collected from a Permanent Counting Station which operates year-round.

Table 6/ Traffic Volumes and Accident Rates, 1980-82 and Nov/83 to Oct/84, Hwy 400, IBC Evaluation

Accident Rate Comparison

Highway 400 -- Hwy 401 to Rutherford Road

	1980	1981	1982	83-84
1. Hwy 401 to Finch Ave.	1.5	1.5	0.6	0.8*
2. Finch Ave. to Hwy 7	0.7	0.7	1.0	0.9*
3. Hwy 7 to Rutherford Rd.	0.6	0.6	0.7	N/A

* Calculated for the area adjacent to IBC only.

Volume Comparison

Highway 400 -- Hwy 401 to Rutherford Road

	1980	1981	1982	83-84
1. Hwy 401 to Finch Ave.	91 050	91 500	91 500	116 500
2. Finch Ave. to Hwy 7	58 700	58 250	58 250	74 750
3. Hwy 7 to Rutherford Rd.	46 700	47 350	47 100	50 150

2/ Based on the above-noted recorded volumes, the MV-km (million vehicle-kilometres) of travel recorded within the study area for the 1983-84 period was as follows:

$$\text{MV-km} = \text{Annual Average Daily Traffic (AADT)} \times \frac{365 \times \text{Section Length}}{1\ 000\ 000}$$

Therefore for 1983-84:

$$\text{MV-km} = \frac{74\ 738 \times 365 \times 1.7}{10^6} + \frac{116\ 480 \times 365 \times 2.3}{10^6}$$

$$= 46.37 + 97.79$$
$$= 114.16$$

3/ Traffic volumes in 1982 yielded the following million vehicle-kilometres of travel:

$$\text{MV-km} = \frac{91\ 500 \times 365 \times 2.3}{10^6} + \frac{58\ 250 \times 365 \times 1.7}{10^6}$$

$$= 76.81 + 36.14$$
$$= 112.95$$

4/ The volumes registered in 1981 were the same as those in 1982. Therefore MV-km for 1981 = 112.95.

5/ In 1980, registered volumes generated the following MV-km:

$$\text{MV-km} = \frac{91\ 050 \times 366 \times 2.3}{10^6} + \frac{58\ 700 \times 366 \times 1.7}{10^6}$$

$$= 76.65 + 36.52$$
$$= 113.17$$

3.1.1.5/ Comparing Volume with Collisions

Comparing the volume information against the collision data the following information was generated:

1/ In 1980, there were 32 barrier collisions and the median barrier accident rate (AR) (i.e., barrier collisions per MV-km) was:

$$AR(80) = \frac{32}{113.17} = 0.28$$

$$\text{where AR} = \frac{\text{\# of accidents}}{\text{MV-km}}$$

2/ In 1981, 41 median barrier collisions were recorded and the AR was:

$$AR = \frac{41}{112.95} = 0.36$$

3/ In 1982, 56 barrier collisions were recorded and the AR was:

$$AR = \frac{56}{112.95} = 0.50$$

4/ In the study period 1983-84, 34 median barrier collisions were recorded yielding an AR of:

$$AR = \frac{34}{144.16} = 0.24$$

5/ In 1980, 21 persons were injured in median barrier accidents. This represents a ratio of 0.19 persons/MW-km.

6/ In 1981, 19 persons were injured in median barrier accidents. This represents a ratio of 0.17 persons/MV-km.

7/ In 1982, 33 persons were injured in median barrier collisions. This represents a ratio of 0.29 persons/MV-km.

8/ In the 1983-84 study period, only 11 persons were injured in median barrier collisions. This represents a ratio of 0.08 persons/MV-km.

9/ In 1980, the estimated property damage for median barrier accidents was $93 500, including barrier damage. This represents a cost of $826.19/MV-km.

10/ In 1981, the estimated property damage for median barrier accidents was $105 245, including barrier damage estimates. This represents a cost of $931.78/MV-km.

11/ In 1982, the estimated property damage for median barrier accidents was $147 475, including barrier damage estimates. This represents a cost of $1305.67/MV-km.

12/ In the 1983-84 study period, the estimated property damage was $101 505. This represents a cost of $704.11/MV-km, excluding barrier costs.

3.1.2/ Summary

Based on the above-noted observations, TM&EO wishes to make the following comments:

1/ In estimated property damage per million vehicle-kilometers travelled, the IBC barrier system compares favourably to the box beam system. In our view, this is principally the result of fewer reported incidents per MV-km within the study area. However, severity of incidents appears to have held constant since the reported damage per median accident appears consistent considering the price per collision with the box beam and a reasonable inflation rate.

In addition, it should be noted that in the majority of cases a cost estimate of damage to the box beam barrier was supplied to the investigating officer by the MTC District Offices. No such estimate of the cost of damage to the IBC barrier was available. Consequently, new property damage estimates for the 1983-84 study period may be

marginally higher than originally shown, depending on estimates of repair costs now available from District Maintenance.

2/ In reducing personal injuries, the IBC barrier system compares favourably to the box beam system. A reduction of 55% is significant and worthwhile from a safety point of view.

It is interesting to note, however, that while the apparent vehicle damage per incident was the same when comparing the soft system (box beam) with the more rigid IBC system, the number of persons injured per million vehicle-kilometres of travel was nearly doubled with the soft system.

3/ Since the representation of rear-end collisions, primary barrier impacts, and secondary barrier impacts remained constant it is safe to assume driver behaviour and patterns on the whole did not change.

4/ Proximity to the new barrier by vehicles in the passing lane indicated that despite the bulk of the IBC barrier motorists were not inhibited by its proximity to the driving lane.

5/ Debris and some minor snow build-up during the course of the year may indicate some maintenance problems were encountered by District staff during normal maintenance operations.

6/ As indicated by Tables 2 to 5, the number of collisions where vehicles clearly returned to the driving lanes after median barrier impact increased significantly with the installation of the IBC barrier system. Further, almost 90% of these collisions occurred during cold weather conditions when freezing was apparent. In addition, most of these accidents resulted in secondary collisions with motorists travelling in other driving lanes. Fortunately, injuries were kept to a minimum.

Based on the above performance it is our opinion that the contents of the IBC system probably froze, resulting in a near rigid barrier system. This is further supported by observations of ice build-up around the base which is certain to retard lateral displacement. In

view of this, we contend that during cold weather the IBC barrier system is similar in performance characteristics to other rigid systems such as concrete barriers.

In warmer weather, the IBC system exhibited some deformable characteristics similar to W-shaped steel beam, or Thrie-beam. Therefore it is recommended the IBC system performance be compared with systems more rigid than the box beam to fairly evaluate its performance.

7/ In four years of collision experience there was NOT a single rollover incident recorded. Both systems obviously performed adequately in this regard.

8/ Over the entire study period only one median barrier penetration was recorded and that was with the box beam system. The intruder was not a heavy truck but merely a mid-sized passenger vehicle navigated by an impaired motorist. Although a reduction of one incident is not statistically significant, TM&EO feels it is safe to say the IBC is less conducive to this type of problem than box beam barrier systems.

9/ The number of incidents involving disabled vehicles in the passing lanes rose significantly since the IBC barrier was installed. While this does not suggest anything about the performance of the barrier, it does suggest the IBC system should not be installed at any location where shoulder widths will be sacrificed. In the case of the Hwy 400 installation it is recommended the various types of barriers be reviewed and a system be selected for use on Hwy 400 which performs safely and efficiently but maximizes the integrity of the median shoulder.

It is the opinion of this office that the IBC is not suitable for use at the present Hwy 400 location for this reason.

3.1.3/ Conclusions

1/ Due to the apparent reduction in personal injuries reported in the 1983-84 study period, the IBC barrier system appears to be at least as safe as the box beam barrier system.

2/ Barrier systems should be selected on the basis of their design, application requirements, and maintenance features. They must maintain or improve existing safety levels both in the median and immediately adjacent to it. Due to performance difficulties involving disabled vehicles in the passing lane, it is recommended that the IBC barrier system not be used on narrow medians where the integrity of the median shoulder cannot be maintained.

3/ Finally, it is interesting to note that while the price per collision remained the same for incidents involving the box beam versus IBC barrier systems, the total number of persons injured declined noticeably. Traditionally, this would not have been thought possible. In fact, it still may not be true despite our recent records.

Due to the relatively small sample size and the comparatively minor differences in performance, it is recommended that further collision analysis be conducted to confirm the findings of the 1983-84 study period.

* * * * *

This concludes the report on accident records as provided by the TM&EO. The following are some additional observations on police reports of accidents and a final summary.

3.2/ Comments on Accident Records

Through normal hours the traffic on the test section is very dense.

With regard to the type of collisions involving the IBC barrier, there is basically little difference in pattern compared to earlier collisions with the box beam installation.

Typically, the predominant collision type is primary impacts by out-of-control cars or vans, originating from all lanes but with the majority from the lane adjacent to the barrier. Some of these vehicles rebound back into the adjacent lane, although all encroach upon this lane because of the lack of shoulder space. The tendency of vehicles rebounding into the travelling lane was more pronounced with the IBC barrier (9 times in one year) than with the box beam (7 times in three years).

Disabled vehicles parking adjacent to the IBC barrier constitute a hazard as they encroach on the closest lane. There were three injury accidents (among 34 collisions) which were caused by such a disabled vehicle being hit by a travelling vehicle. Otherwise, very few injuries were a direct result of barrier impact.

It should be noted that no heavy vehicle (bus or heavy truck) collided with the IBC barrier during the year of monitoring.

A shoulder width of at least 3 m from the outside wall of the barrier seems to be necessary to avoid the aforementioned encroachment hazard. This should increase the space requirement for IBC installations compared to the concrete N.J. or other steel beam barriers, but this has not been taken into account in the economic study.

More details on accident observations are presented in Section 4.

3.3/ Summary of Accident Experience

The relevant information is summarized in Table 7. The one year IBC-related figures are lower than the figures for box beam collisions, especially the injury rate. During the first three years there seem to have been changes in traffic flow patterns due to design changes near the ramps of Hwy 401-400. It is difficult to draw definite conclusions but it is safe to say that IBC barrier performance is not inferior to the box beam performance (for all classes of vehicles, including cars). The measured improvements in those rates may be due to various causes, such as improvement of traffic flow, and barrier features. There were also unusually severe conditions during the winter of 1981/82.

The average accident rate for all accidents on Ontario freeways between 1978 and 1982 was about 0.8 (accidents/MV-km).

Table 7/ IBC Barrier and Box Beam Accident Rates and Property Damage

	Box Beam (3 year average)	IBC, 1 year
Accident Rate (major collisions reported)	$\frac{(0.28 + 0.36 + 0.50)}{3} = 0.38 \frac{\text{accidents}}{\text{MV-km}}$	$0.24 \frac{\text{accidents}}{\text{MV-km}}$
Property Damage Rate	$1021 \frac{\$}{\text{MV-km}}$	$704 \frac{\$}{\text{MV-km}}$
Injury Rate	$\frac{(0.19 + 0.17 + 0.29)}{3} = 0.21 \frac{\text{injuries}}{\text{MV-km}}$	$0.08 \frac{\text{injuries}}{\text{MV-km}}$

4/ VIDEO MONITORING AND ON-SITE OBSERVATION*

4.1/ Introduction -- Use of Video Surveillance Techniques in General

Video monitoring is becoming a widely used technique for the observation of real-time performance of transportation facilities. The general use of video surveillance (VS) techniques can be classified by purpose of surveillance which, in turn, places a restriction upon the type of instrumentation employed.

Traffic management is currently the major area of application of VS techniques. A large VS system was developed by MTC along a part of the Queen Elizabeth Way corridor to assist in the fast and efficient control of traffic flow under abnormal situations (accidents, area recognition, stalled vehicles etc). Approximately 10 cameras are placed at strategic locations to allow uninhibited observation of the entire corridor. This type of VS system also allows study of time traffic patterns, volumes, occupancy per lane as well as patterns of driver behaviour.

Another use of the VS technique is for monitoring of new appurtenances to evaluate real-life performance. This careful evaluation of new installations is required to supplement test results obtained from testing facilities. Results of this analysis are necessary in order that policy decisions can be made with regard to the use of these new appurtenances. The VS technique used for this application does not require a massive capital investment, however, it must be specifically designed for a particular location.

The development of automated VS systems which utilize pattern recognition techniques to recognize, for example, licence numbers, can be used for police and research purposes. Such techniques have been applied by law enforcement officers in the United Kingdom and were claimed to be useful for recognition of stolen vehicles. Automated VS techniques will find more applications when the system costs are reduced.

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*Note: This chapter was prepared by Messrs A.L. Kazakov and C.T. Blaney of R&D Branch.

4.2/ Introduction to IBC Monitoring System

To support the evaluation of the IBC barrier performance it was decided to use a VS system. An analysis was performed of the possibility of automating a VS system with the purpose of having both real-time accident recording and time-lapse recording. Several possible methods of automation were considered but the timing and costs of development and application of these techniques were prohibitive. However, the suggested methods can be adapted for other installations should the need arise.

Monitoring of the entire 3.75 km of the IBC barrier would require a number of cameras installed at specific locations to fully cover its entire length. However, this VS monitoring was done in support of the information collected by other offices on a regular basis. For the specific purpose of monitoring the barrier, the cost of equipment (purchase of specific cameras, video recorders, construction of camera poles, etc.) and installation would be prohibitive. As a result it was decided to use one camera monitoring about 1 km of the barrier to obtained a sample real-life performance of the barrier.

4.3/ Description of the Installed VS System

In order to observe the IBC barrier on a 24-hour basis, an available video camera and time-lapse recorder were used. This combination made it possible to review and study events at a later time.

A Panasonic video camera was erected on the Sheppard Avenue bridge which overpasses Hwy 400. The camera was mounted in a protective housing and located on the north side of the structure looking at traffic travelling between Sheppard and Finch Avenues. The camera was connected through a series of video amplifiers to a Panasonic Time-Lapse Recorder (model 8050) located at the Patrol Yard on Arrow Road.

Surveillance of the IBC barrier began on January 10, 1984, and continued until the end of the year.

4.4/ Interpretation of Video Tapes

4.4.1/ Introduction

VS monitoring allowed the observer to judge such things as driver attitude and performance of the barrier in normal traffic conditions as well as accident situations. Findings from the VS system supported information obtained by other means such as the accident collision study, maintenance study and field surveys.

Only those accidents which occurred within a selected camera range could be accurately evaluated. Difficulties arose for evaluation of night-time accidents, although the video information, in conjunction with police reports, made a much clearer picture of the actual events.

4.4.2/ Driver Attitudes

From the recorded tapes, the barrier seems to cause no discomfort nor pose any threat to drivers using the passing lanes closest to the barrier. During peak traffic periods, all lanes appear to be occupied to their capacity. Because of its height, the barrier acts as a glare screen at night for oncoming vehicles. Also, other drivers pass each other unaware of happenings in the opposing direction lanes. Hence, an accident in one direction tends not to affect the flow of traffic in the opposite direction.

4.4.3/ Winter Maintenance

From VS observation the IBC barrier appeared to pose no great problems for winter maintenance crews. After the barrier was erected, and because of the colour of the barrier, an additional set of reflectors were installed on the barrier lid. Snowplows appeared to be able to plow close to the barrier without making contact.

4.4.4/ Reaction of Drivers During Accidents

Accurate details of the types of damage suffered by the barrier could not be observed by reviewing the recorded tapes, but by combining the OPP accident reports together with the recorded events, we were able to associate some of the barrier contact accidents with the damage done to the barrier.

In accident-prone situations involving cars stopped adjacent to the barrier, the traffic flow was generally not interrupted. However, although drivers were able to adjust for the stalled car and proceed around without causing an accident, they were inhibited from driving in the normal manner.

The following are some events observed from recorded video tapes.

- A panel van stalled on lane #3 in the northbound traffic just south of the Finch Avenue exit. Traffic was light on this particular day (14th July, 1984, at 18:24 h) and motorists behaved in a very orderly manner in going around this stalled vehicle, which managed to restart and continue 16 minutes later.

- In another situation, a car came to a stop on lane #1 (closest to the barrier) in the northbound lanes. In this case, the driver could be observed coming out of his car and standing between his car and the barrier. This particular event occurred on July 22, 1984, at about 10:50 h. Here again, the stalled vehicle did not cause traffic in that lane to come to a stop, but instead traffic moved on around the stalled vehicle.

- Another similar situation occurred on July 24, 1984, at approximately 17:08 h, when a car stalled again in lane #1 in the northbound lanes and again vehicles continued on their way by just moving around the stalled car without stopping.

- On July 27, 1984, at approximately 21:20 h, a car possibly struck the barrier with a glancing blow, again from lane #1 of the northbound traffic. Although it was dark and details were difficult to see, the video recording showed that when the OPP arrived that both the OPP and the 'damaged' car moved over to the shoulder.

The safe passage of vehicles around a stalled vehicle did not occur in every case. On one occasion, for example, a panel van appeared to blow its cooling system and emitted a large cloud of steam at 20:19 on July 28, 1984, southbound adjacent to the IBC barrier. The van came to a halt next to the barrier. Occupants from the van exited from the vehicle and attempted to make repairs. Several cars and buses safely went around the

van. Two minutes later a car skidded in the fluid spilled by the van onto the road surface, but was able to safely recover control. A car then stopped in front of the van and tried to render assistance.

Approximately 4 minutes after the van stalled, another car rapidly changed lanes to avoid hitting the van and struck a station wagon three lanes from the barrier. This car then continued on into the ditch. After this happened a number of vehicles pulled over to the shoulder to render assistance. The station wagon was blocking the right-most lane, but the other drivers were able to manoeuvre around this accident. Nine minutes after the van stalled, it moved over the shoulder under its own power after traffic was stopped.

The OPP arrived 12 minutes after the van stalled and placed flares around the station wagon. A second OPP car arrived two minutes later. The police moved the car to the shoulder of the road and normal traffic flow resumed shortly thereafter. An ambulance arrived 21 minutes after the initial impact to take the injured people to the hospital.

In addition to the accidents which do not involve actual contact with the barrier there were a number of accidents in which vehicles were observed to strike the median barrier. One such accident occurred on March 23, 1984, at approximately 10:30 in the morning in the southbound lanes. One vehicle appeared to cut off the other into the barrier and both vehicles contacted it. A later field observation of the barrier revealed an approximately 0.5 m long rip in it.

There are quite a few video records of drivers and passengers leaving vehicles stalled against the barrier and standing around the vehicle and even sitting and standing on the barrier, either waiting for emergency assistance or for a chance to run across the highway -- risky and dangerous in either case.

4.4.5/ Police Usage

Frequently, the OPP covering Highway 400 would request a viewing of an accident which occurred within camera range. The OPP Officer would then have an opportunity to view the events during any accident as they occurred. This, along with eye-witness reports, put the police officer in a better position to evaluate the accident. The video recording also

represents a permanent record of the event. Even if the exact events were not clearly visable, the timing of the events was available in great detail from the VS system.

4.4.6/ Problems and Insights into VS Systems Usage

Some of the problems encountered with the video recorder were individually isolated and modifications were made to the system to overcome the problems. Initially, during the winter months, the video recorder was occasionally cutting out, causing a disruption in recording. This was due to relatively high humidity levels and a high ambient temperature in the room where the recorder was located. This particular problem was overcome by moving the system into another room where more favourable conditions existed.

Another problem encountered was overheating of the recorder due to continuous 24-hour recording. This overheating caused the recorder to automatically shut off, hence there were gaps in some of the recordings. This problem was overcome by installing a continuously-running fan in the cabinet in which the recorder was placed. Also, larger ventilation holes were made in the cabinet to allow for a continuous flow of cooling air around the video recorder. The video recorder was serviced on a regular basis to avoid excessive build-up of dirt and magnetism on the recording heads.

We had extremely bad luck during the month of August when the camera was struck by a severe wind storm which some people claimed to be a tornado. The protective shroud covering the camera was damaged and the camera was turned a 45° angle from its normal line of sight. Repairs had no sooner taken place when approximately two weeks later the system was struck by lightning. The lightning damaged the video boosters and, because of a series of difficulties, the monitoring system was inoperative for a period of five weeks.

Whenever repairs of the VS system are required at the Sheppard Ave. overpass it is necessary to close a lane in both directions adjacent to the barriers. This is costly (approximately $500) and one should schedule such work to coincide with other maintenance to be done. Also, the closures may only take place between the hours of 9:00 a.m. and

3:00 p.m. in order to avoid adverse effect on the rush hour traffic flow. Repairs requiring removal of part of the monitoring system mounted on the Sheppard Avenue overpass also require a lane closure to re-install the repaired parts, thereby further increasing the cost of the repair.

4.5/ On-Site Observations

4.5.1/ Physical Appearance

The physical appearance of the IBC barrier tends to be a very subjective item. There have been a high number of barrier contacts during the first year of its operation resulting in unsightly appearance of the barrier. The results of an on-site survey of barrier damage is presented in Table 8. As may be seen from this table, there were over 200 damaged spots on the barrier. For the most part, this damage would not affect performance of the barrier in an accident situation, but it does affect barrier appearance.

The barrier is rusting in a number of areas in places not damaged during accidents. This can clearly be observed in Figure 4. The steel in the barrier can be seen rusting where a bolt attaches the lid to the rest of the barrier. The long-term effects of this rusting would seriously impair barrier appearance and, if exposure were long enough, its strength as well.

The barrier appears to be dirty during the winter months when there is sanding on the highway and no rainfall to wash off the barrier. There is a large build-up of debris adjacent to the barrier. This is more pronounced near a bump in the highway where slush and ice falls from the vehicles and comes to rest near the barrier. A bump such as this exists at the Finch Avenue overpass.

4.5.2/ Barrier Damage

Figures 5 to 6 clearly show the types of damage inflicted upon the barrier from glancing blows by vehicles. Figure 7 shows the peeling and flaking of the polyvinyl coating. The damage which is illustrated here

would not affect the performance of the barrier but it does affect the aesthetics and longevity of the barrier system. The damaged panels shown in Figure 5 were subsequently replaced by MTC maintenance staff in an operation described in Chapter 7.3, Repair Procedures. The number of observed spots of "slight" to "severe" damage are listed in Table 8.

Table 8/ IBC Barrier Damage as of November 13, 1984

Location	Damage Scale*				Total
	Slight----------			----------Severe	
	1	2	3	4	
Northbound	81	23	5	1	110
Southbound	83	25	8	3	119
					$\sum$ = 229

* Scale: 1 = Varying from a slight rub to a scrape in the polyvinyl coating.
2 = Indentation of exterior structure.
3 = Indentation into central structure.
4 = Indentation requiring barrier section replacement or patching.

* **Note:** The observations were made from the highway shoulder, a distance of approximately 20 m, so that only the more severe damage could be clearly observed. Some slight scratches may have gone undetected. Furthermore, several adjacent damage traces could have been caused by a single accident event.

4.5.3/ Maintenance and Repair Procedures

A detailed description of maintenance procedures is given in Section 7, Maintenance Operations Report. Discussion in this section will be limited to on-site observations of the procedures.

Figure 8 shows a damaged section of the barrier. The barrier was moved approximately 25 cm from the original alignment. The damage occurred on July 21, 1984, when a single car lost control due to mechanical failure of the steering system and struck the barrier at a high angle of impact. In the figure, the lid of the barrier has been removed and the crew is awaiting the arrival of the vacuum sewer cleaner to remove the stone ballast and subsequently realign the barrier and replace two damaged panels. This operation proceeded smoothly but was quite time-consuming as the ballast had to be dumped temporarily at a patrol yard for later re-use following the panel replacement.

Another type of barrier repair was observed. Some damaged sections could be repaired by overlaying a panel directly on top of the damaged ones. The process is shown in Figures 9 and 10. This type of repair appeared to be as time-consuming as replacement of the damaged panel. Figure 10 shows that this type of repair could give the barrier a "patchwork" appearance with a high degree of contrast in colour between different panels or sections within the same panel.

It should be noted that all minor and major hits, even those requiring repair work on the IBC, would probably not have caused any damage greater than tire marks to a concrete barrier.

There is a large amount of sand and debris which accumulates next to the barrier and in the catchbasins because the highway in the area of the IBC barrier has a centreline drainage system. Figures 11 to 13 show the removal of this material from the catchbasins. The operation appeared to proceed smoothly, although a number of the catchbasin lids appeared to be difficult to remove because of the build up of debris and the confined space in which maintenance must be undertaken.

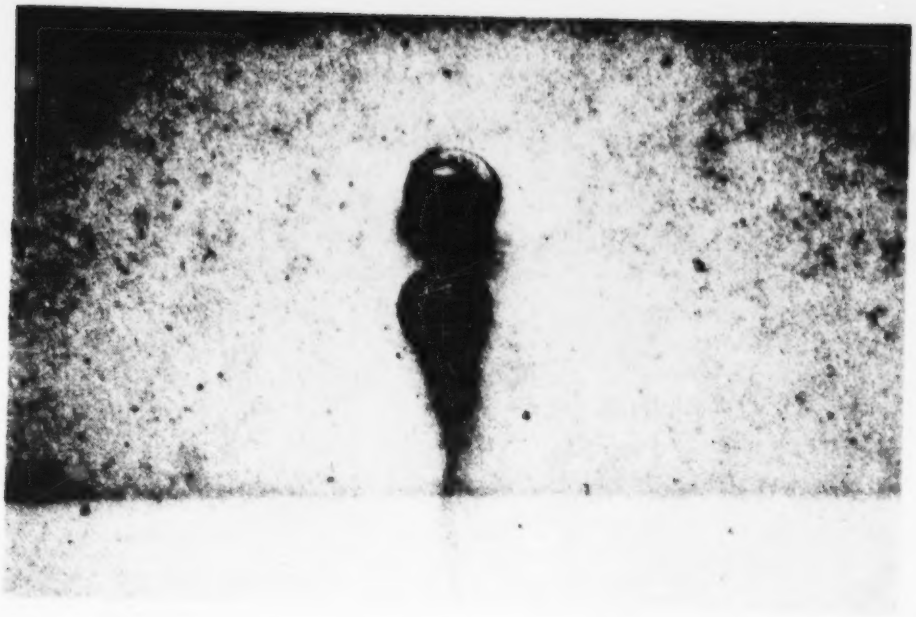

Figure 4/ IBC Barrier Rusting around Bolts

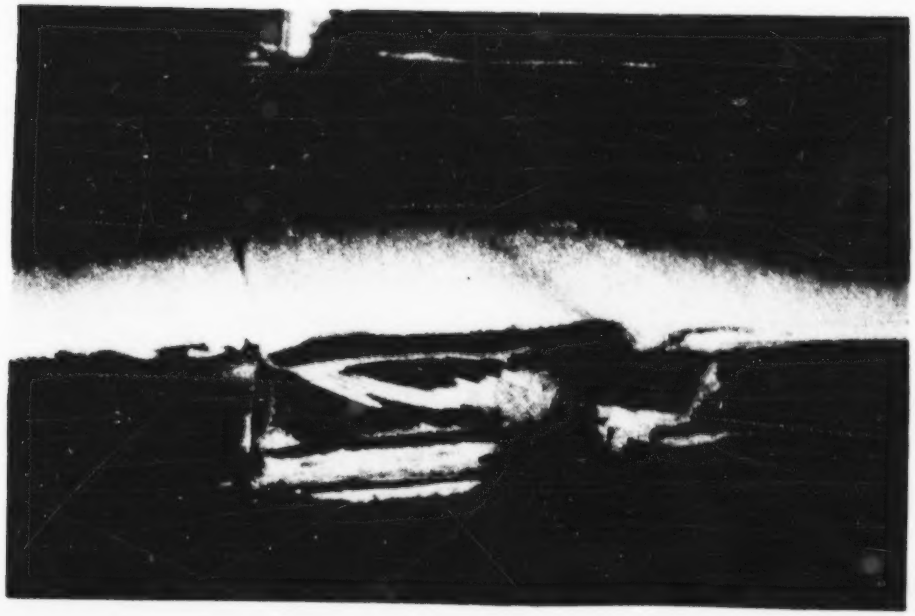

Figure 5/ Barrier Panel Damage

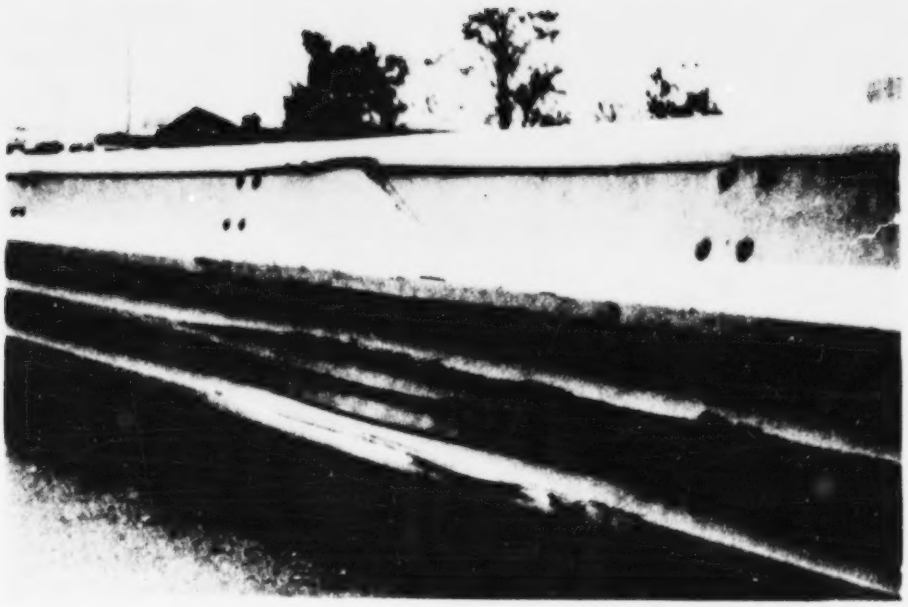

Figure 6/ Barrier Damage

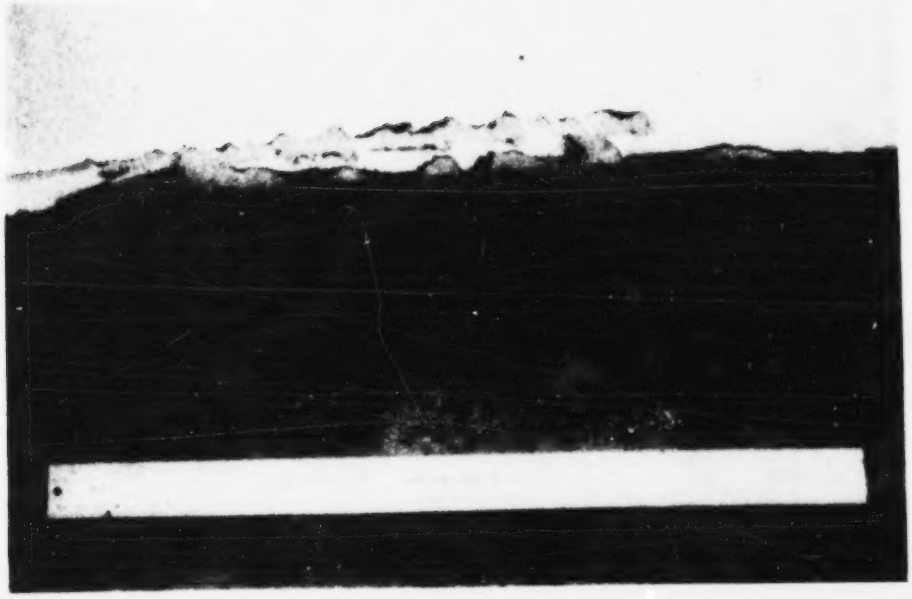

Figure 7/ Magnified Image of Damage Shown in Figure 8

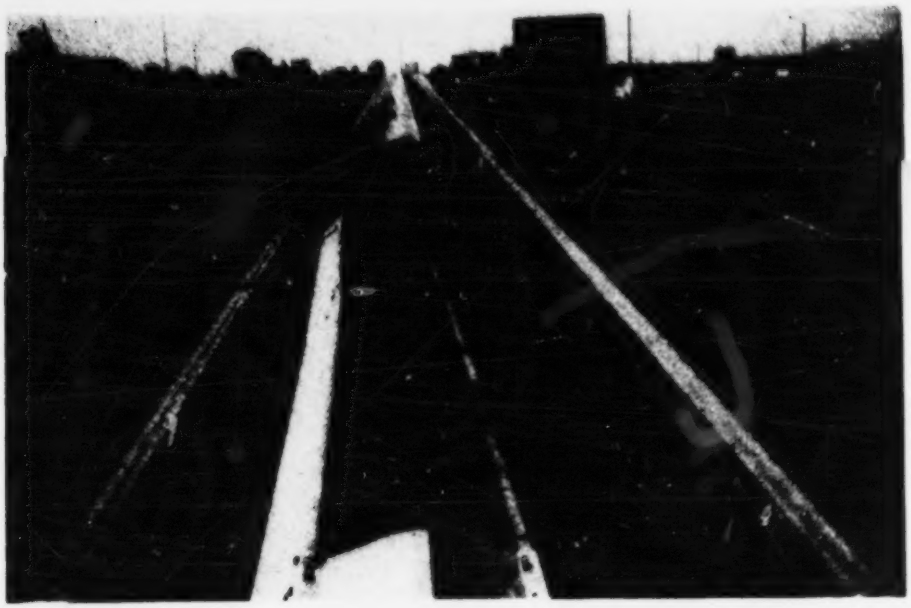

Figure 8/ Misalignment of the Barrier due to a High Angle Impact (Lid Removed)

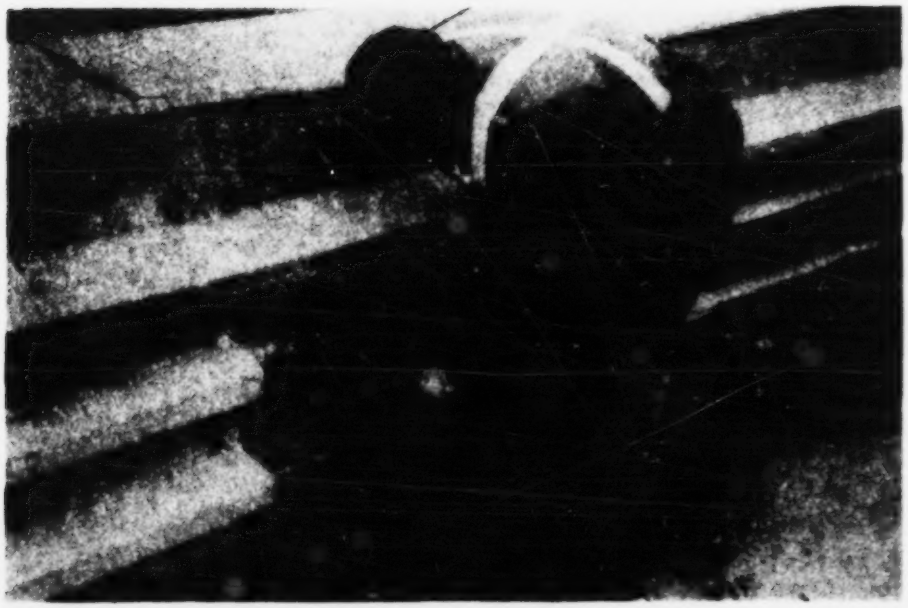

Figure 9/ Replacing Damaged Panel

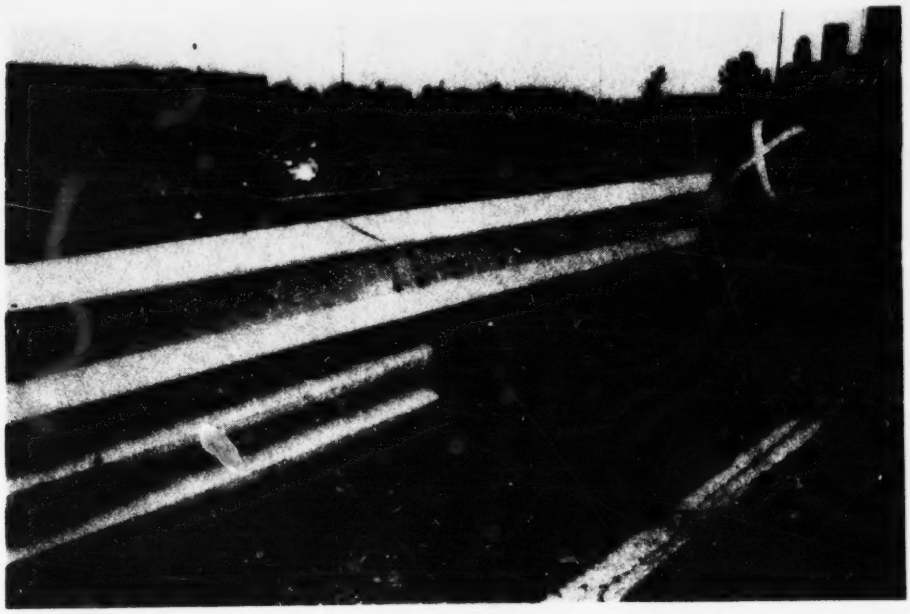

Figure 10/ IBC Barrier after Panel Repair

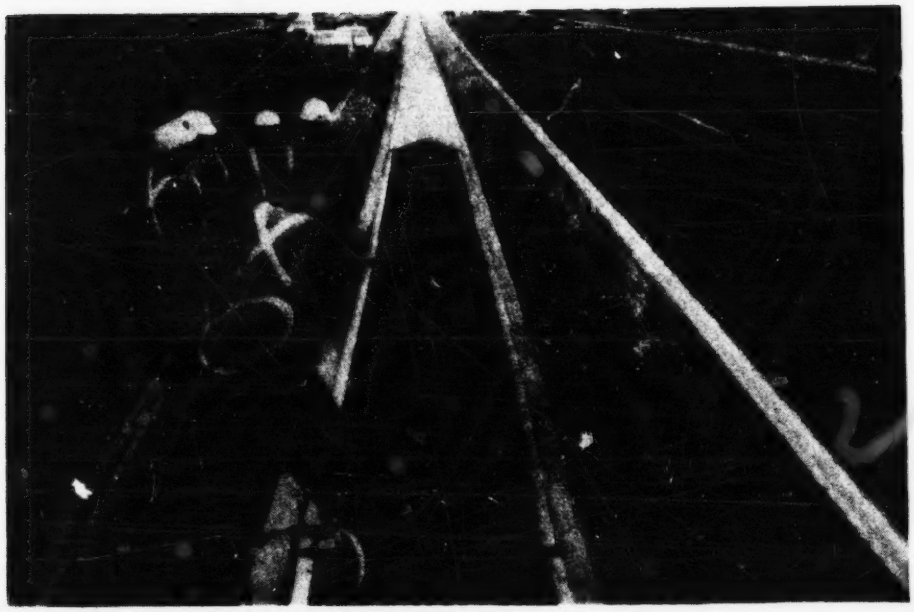

Figure 11/ IBC Barrier Prepared for Catchbasin Maintenance

Figure 12/ Vacuum Truck in Operation

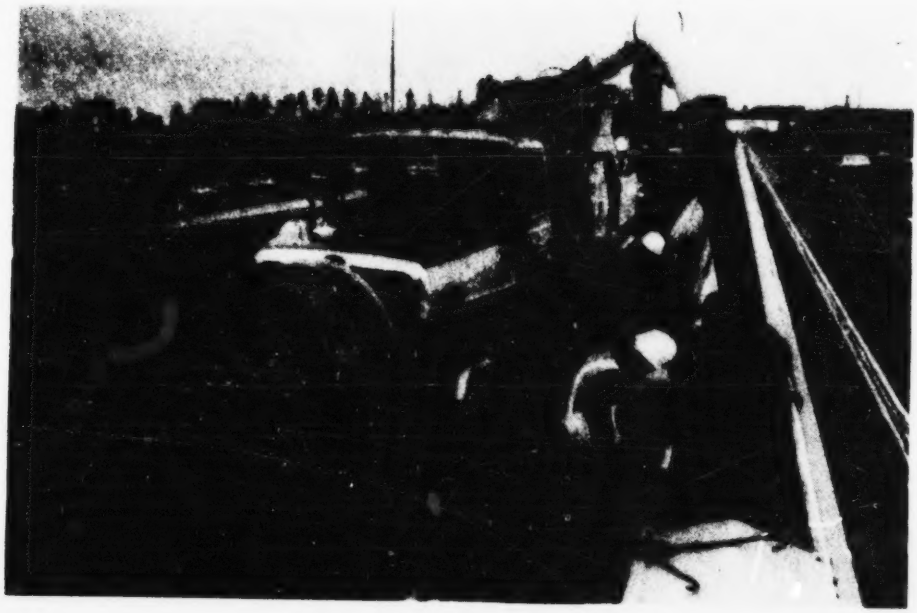

Figure 13/ Removal of Debris from the Bottom of a Catchbasin

5/ CONSTRUCTION REPORT -- CONTRACT 83-314*

5.1/ Recommendations

1/ The use of construction markers TC-52 to separate heavy traffic from work area appears unsafe for the workers. A more protective barrier should be used for the safety of the construction forces (i.e., a temporary New Jersey Barrier).

2/ The use of the temporary transition as shown on Dwg. #12700 was not implemented as it required time-consuming work for installing, removal of material, and repairs to existing asphalt four or five times throughout the duration of the contract. An alternate method was adopted by closing the new IBC barrier to the existing box beam barrier, filling all bins with stone except the final bin which had stiffener beams temporarily installed. The new barrier was bolted to the existing barrier and tapered so as not to present any sharp obstructions to traffic. Timing is of the essence when using this alternate method for the week-end shutdown of the contract.

3/ Asphalt pads placed at drainage swales required too much valuable time for the asphalt to set up and as a result the weight the IBC barrier placed on the pads caused some settlement. Also, the #10002 MK-VII standard bulkhead has no bottom flange as do the side edges, therefore, it acts as a knife cutting into the asphalt pad. This problem could be resolved if the asphalt pads could be placed approximately one day prior to the barrier and also a supporting flange could be designed for the bottom edge of the bulkhead.

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* NOTE: This section was prepared by Messrs M.D. Wanamaker and C.R. Watson of Central Region.

5.2/ Design Problems (Roadway)

1/ Location of the IBC barrier (i.e., its alignment) is vague, shown on Dwg. #14800 only.

2/ No plans with contract showing existing conditions, i.e., elevations or alignment.

3/ Maintenance problems will arise when repairing IBC barriers. To repair one panel, the stone must be removed from adjacent panels then replaced. This will necessitate an eduction machine.

4/ Overlap of existing box beam guide rail at overhead sign footing omitted in the removal estimate. This added 103.6 m to total.

5/ The galvanized panels were supplied with no intermediate lengths, as were the plastic coated panels. This created installation problems at drainage swales. The galvanized panels had to be field drilled to accept the bulkheads at the proper locations.

6/ The asphalt pad over the raised median on Finch Avenue structure had no provision for treatment at existing expansion joints. Flexcell material was placed in asphalt pad at these locations.

7/ There was no item in contract for the removal of steel beam guide rail. Fifteen metres of tapered section had to be removed in order to connect new IBC barrier to existing steel beam guide rail.

8/ Alignment chainage at Sta. 270+00 (Drainage Swale) for installation of steel beam guide rail was in error and guide rail post had to be set in steel base on concrete catch basin.

9/ Drawing #10000 shows 8 ea. #12 x 3/4" lid screws are required.

Drawing #10003 shows 4 ea. apertures in lid are required for screws.

Material supplied by MTC provided for only four screws. This required the drilling of four extra holes. The size of the screws

was increased from #12 to #14. This required enlarging four existing holes. This resulted in a quotation request for a new item to the contract to cover the additional work.

10/ Revisions made after contract awarded:
a) size of lid screw changed
b) box beam transition taper length
c) spacing of posts
d) attachment plates added to channel.

These changes necessitated force accounts.

5.3/ Specifications and Standards

1/ Special Provisions (Operational Constraints) allowed contractor to work during daylight hours Monday to Friday with no constraint made for Monday 7-9 a.m. or Friday 3-6 p.m. -- rush hours on a heavily travelled freeway.

5.4/ Construction Problems

1/ As the IBC barrier was placed on the existing asphalt median with no contract item to adjust abrupt changes in existing elevations, there are areas where the new IBC barrier does not have a pleasing vertical profile.

2/ The IBC material supplied by the Ministry was received prior to the MTC construction staff arriving on-site. This created a problem for reconciliation of material, i.e., no bills of lading available. Contractor could not be made responsible for materials as there was an unknown amount and a portion of the material had been allocated for maintenance purposes.

Comments

1/ The 30 working days allotted for the completion of the contract were adequate. The Contractor completed the work with four working days remaining on the contract.

2/ The late season start for the contract presented problems, i.e., snow and removal of box beam guide rail posts which can be removed easier in warm weather with less disruption to existing asphalt.

3/ All MTC field supervision, inspection and layout were completed by one Project Supervisor and one T.C.I. Inspector. One survey crew was used for a total of three days to offset alignment.

5.5/ Miscellaneous

Force Accounts

F-300-CR-83 Remove steel beam guiderail end treatment to allow placing of W-Beam transition.

F-311-CR-83 Repair asphalt in existing raised median caused by the removal of steel beam guide rail.

F-326-CR-83 Place additional asphalt pad on south end of Finch Avenue structure to correct vertical alignment of IBC barrier.

F-343-CR-83 Repair IBC barrier which was damaged due to traffic accident.

Summation of Staff

1 Project Supervisor = 3 weeks
1 Project Supervisor = 12 weeks
1 T.I.C. Inspector = 10 weeks
1 Survey Crew = 3 days

5.6/ Quality Assurance

The inertial medium (stone) with a gradation of 100% passing the 19 mm sieve and 0-5% passing the 9.5 mm sieve was not readily available and had to be manufactured by the supplier.

6/ LABORATORY TESTING OF PEAA/PVC COATINGS

The Chemicals Section of the Engineering Materials Office recieved and tested the following 75 mm x 150 mm samples of IBC barrier panels from the Research and Development Branch.

a) Coated panel, black PEAA coating on one side and bone white PVC coating on other side (12 pieces received).
b) Galvanized steel panel, hot-dip (8 pieces received).

6.1/ Test Procedures

Laboratory tests included measurements for coating thickness, adhesion and impact resistance, as well as salt spray corrosion and accelerated weather resistance determinations. Duplicate test samples of black and white coated sides of the PEAA/PVC panel and the galvanized panel, one panel of each being scored, were exposed in the salt spray cabinet for 1500 h according to ASTM B117 procedure and for 2500 h in the Atlas Twin Arc weatherometer operating at a temperature of 55°C and using a 102-18 cam cycle as per ASTM D822.

6.2/ Test Results

Laboratory test results indicate the following:

1/ Physical Test Results (Table 9)

a) The thickness of the white PVC coating is about 50 μm greater than that of the black PEAA coating which is 225 μm.

b) The thickness of the galvanizing under the PEAA coating (about 20 μm) is approximately 1/5 that of the hot-dip galvanized steel panel.

c) Adhesion and impact resistance of both the white PVC and black PEAA coatings appear to be satisfactory.

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* NOTE: This section was prepared by R. Fujii, Chemical Engineer, Chemicals Section.

2/ Salt Spray and Weatherometer Test Results
(Figures 14 & 15, Tables 10 & 11)

a/ Black PEAA Coated Panels

Disregarding slight blistering along the edges and lifting of the coating at the lower corners of the panels, the black PEAA appears to be in fairly good condition after 1500 h of salt spray exposure. Surface deposits of white zinc salts are evident along the panel edges and scored areas. The top quarter segment of the scored black coating exposed to salt spray has peeled back from the panel (see photo, Figure 14) -- this may have been caused by defective pretreatment of the galvanized surface prior to topcoating.

After 2500 h of exposure in the weatherometer, the black PEAA coating is beginning to show signs of film degradation. The surface of the coating is checking (fine surface cracking) resulting in a loss of gloss due to hazy film of white zinc salts adhering to the coating surface. Otherwise the coating is in good condition (see photo, Figure 15).

b/ Bone White PVC Coated Panels

Other than the formation of a few blisters along the edges and slight delamination of the coating at the bottom corners of the panels, the bone white PVC coated panels are in excellent condition after 1500 h of salt spray exposure. There is negligible white zinc salt formation along the score mark and panel edges and no peeling of the coating has occurred over the scored panel surface.

The bone white PVC coated panels do not show any significant change after 2500 h of exposure in the weatherometer. The white coating appears to be unaffected by ultra-violet radiation during the accelerated weathering test.

c/ Galvanized Steel Panels

Without a protective coating over the galvanizing, white zinc oxides form rapidly on the panel surface under saline conditions. As a

result, pitting of the galvanized surface and spot rusting of the steel substrate occur dependent on the rate of removal of the zinc through sacrificial action. After 1500 h of salt spray exposure, spot rusting is evident as shown by brownish rust stains over the white zinc salt covered galvanized panels.

The weatherometer test results show that the galvanized steel panel is unaffected by exposure to accelerated weathering for 2500 h. White zinc oxides have not formed on the surface of the galvanized panels exposed in the weatherometer because of the absence of concentrated sodium chloride in the water spray.

6.3/ Conclusions

Based on salt spray corrosion resistance and accelerated weathering test results, the black PEAA coated panel does not appear to be as durable as the bone white coated panel. The former seems to be susceptible to film degradation due to the effects of ultra-violet radiation and possible film separation from the galvanized steel substrate. However the black PEAA coated panel should be satisfactory for use on the interior of the IBC barrier structure where it is protected from the elements.

The bone white PVC coated panel has excellent durability, considerably better than that of the uncoated galvanized steel panel in a saline environment and it should have satisfactory performance for the exterior surface of the IBC barrier. The bone white PVC coated panel appears to have comparable durability to that of the vinyl coated steel panel which is being used for noise barrier application.

6.4/ Physical Properties of IBC Barrier Panels

Test Materials:

J. Wear of R&D provided the following 7.6 x 15.2 cm (3" x 6") test panels of IBC barrier for testing:

- 84-S-50500 12 pcs. PEAA/PVC coated panels
  (black one side, bone white one side)
- 84-S-50501 8 pcs. galvanized steel panels

Table 9/ Physical Test Results

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a) Coating Thickness Measurements by Micrometer

84-S-50500 PEAA/PVC Coated Panel	Black PEAA Coating	= 225 μm
	White PVC Coating	= 277 μm
	Galvanizing (one side)	= 14 μm
84-S-50501 Galvanized Panel	Galvanizing (one side)	= 82 μm

b) Total Amount of Galvanizing Determined Chemically (two sides)

84-S-50500 PEAA/PVC Coated Panel = 0.94 oz/ft^2 (40 μm)
84-S050501 Galvanized Panel = 4.66 oz/ft^2 (200 μm)

note: 43 μm of galvanizing = 1 oz/ft^2

Adhesion

84-S-50500 White Side = #5 = 100% remaining
Black Side = #5 = 100% remaining

Impact at Room Temperature 25°C

84-S-50500 White Side = Passes 4.0 N-m
Black Side = Passes 4.0 N-m

Impact at 0°C

84-S-50500 White Side = Passes 4.0 N-m
Black Side = Passes 4.0 N-m

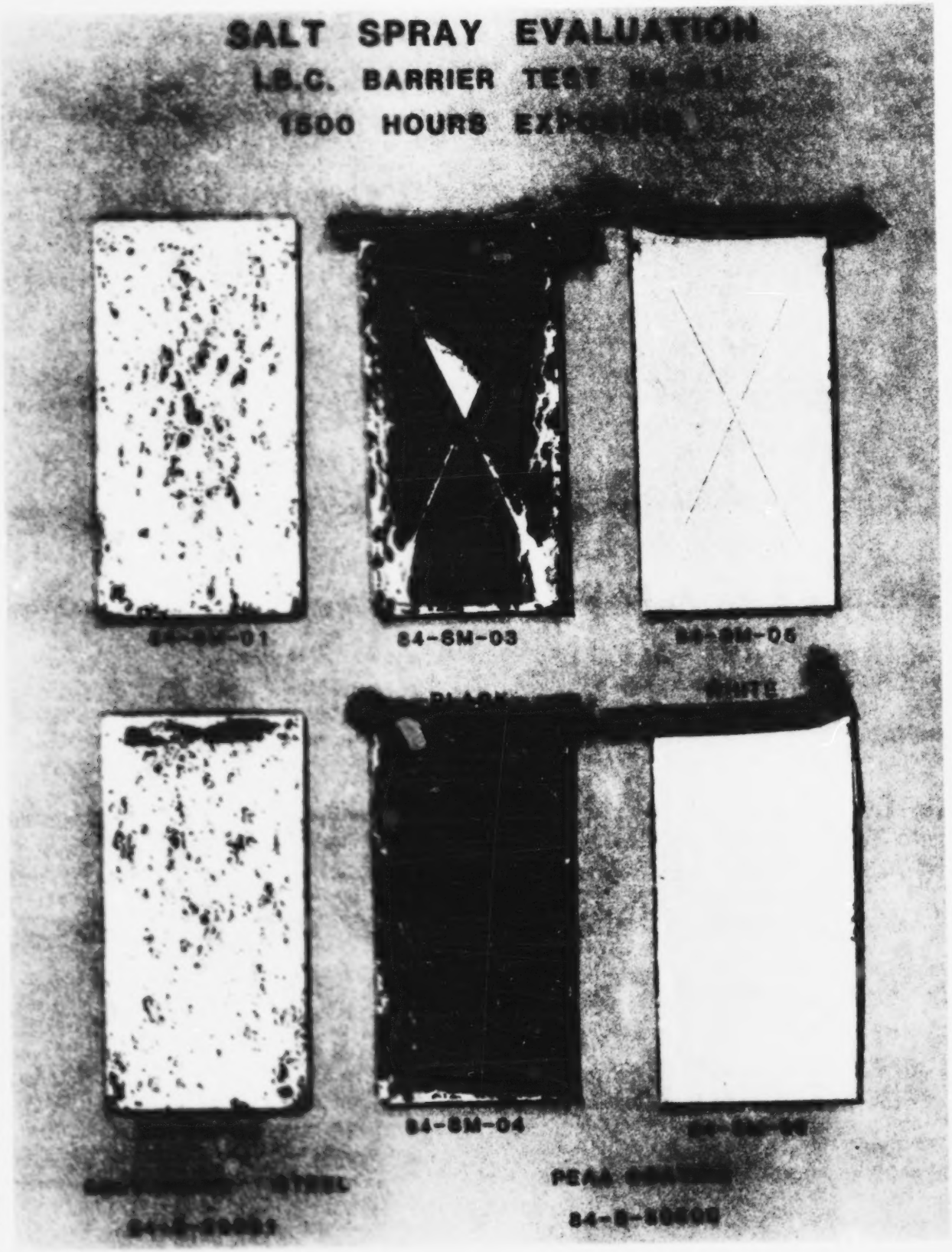


Figure 14/ IBC Barrier Panels, Salt Spray Test Results

Table 10/ IBC Barrier Panels, Salt Spray Test Results

IBC Barrier Panels
Salt Spray Test Results

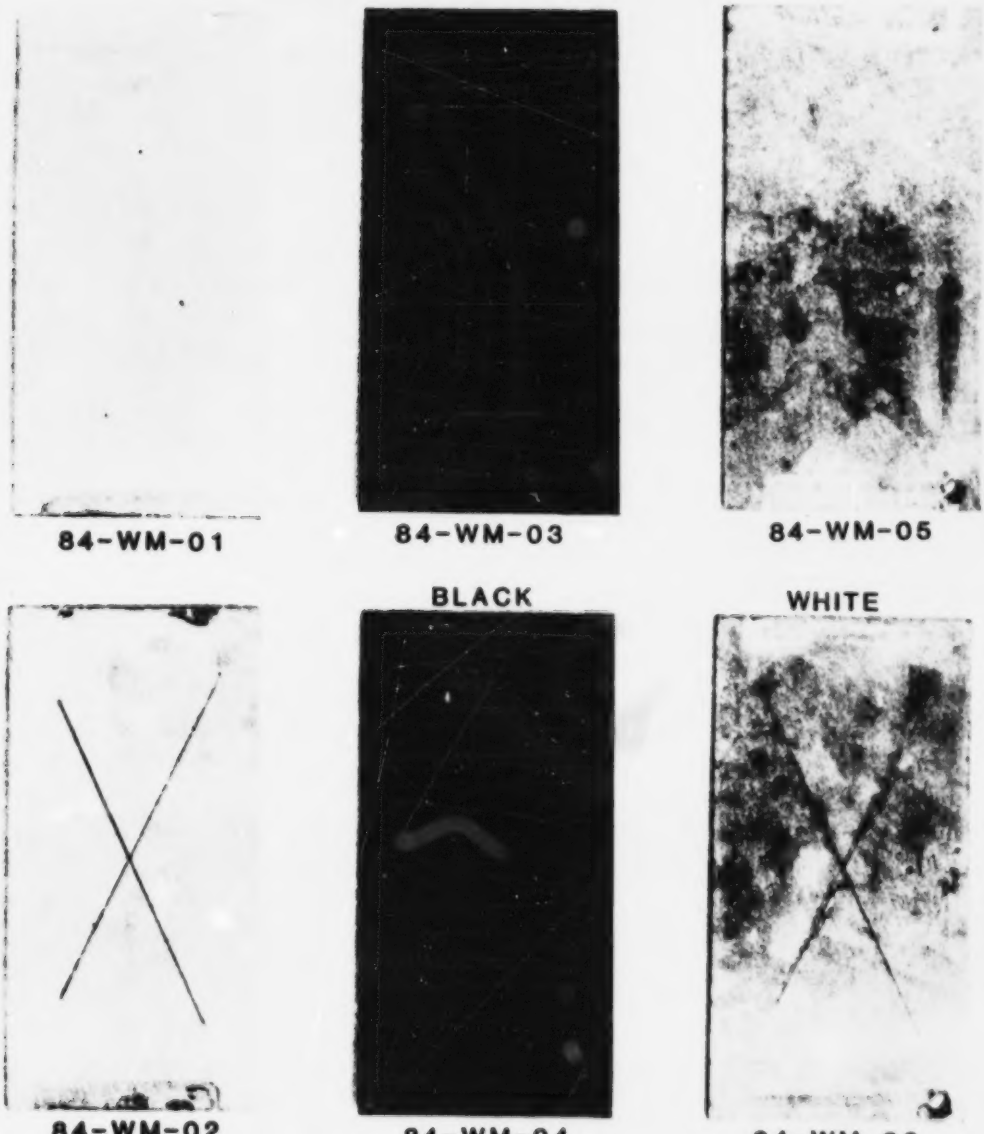
Panel Type	Galvanized Steel (hot dip)		Black PEAA Coating on Galvanized Steel		White PVC Coating on Galvanized Steel	
Lab. Sample No.	84-S-50501		84-S-50500		84-S-50500	
Panel No.	84-SM-01 scored	84-SM-02 unscored	84-SM-03 scored	84-SM-04 unscored	84-SM-05 scored	84-SM-06 unscored
Exposure (hours)						
200	White oxides cover 60% of face of panel.	White oxides cover 60% of face of panel.	Slight lifting of coating at centre of scored panel.	White oxides along edges.	Slight lifting of coating at lower corners.	Slight lifting of coating at lower corners.
600	White oxides cover 75% of face. Brownish spots over face (1%)	White oxides cover 70% of face. Brownish spots over face (0.3%)	Blisters 6F along score. Top quarter segment lifting 2 cm from centre.	Blisters 6F along edges.	Blisters 7F and white oxides along edges.	Blisters 6F and white oxides along edges.
1000	White oxides cover 85% of face. Rust spots over face (3%)	White oxides cover 90% of face. Rust spots over face (1%)	Top quarter segment lifting 4 cm from centre, lifting at lower corners. White oxides along edges.	Blisters 4F along edges. Coating lifting at lower corners about 3 mm.	Blisters 5F along edges.	Blisters 4F along edges.
1500	White oxides cover 100% of face. Rust spots over face (5%)	White oxides cover 100% of face. Rust spots over face (3%)	No change.	Blisters 2F along edges. Coating lifting at lower corners about 6 mm.	Blisters 4F along edges. Coating lifting at lower corners about 6 mm.	Blisters 4F along edges. Coating lifting at lower corners about 6 mm.

Test
Reference: ASTM B117 Salt Spray Test, D714 Degree of Blistering

WEATHEROMETER EVALUATION

I.B.C. BARRIER TEST 84-01

2500 HOURS EXPOSURE



GALVANISED STEEL

84-S-50501

PEAA COATING

84-S-50500

Figure 15/ IBC Barrier Panels, Weatherometer Test Results

Table 11/ IBC Barrier Panels, Weatherometer Test Results

IBC Barrier Panels
Weatherometer Test Results

Panel Type	Galvanized Steel (hot dip)		Black PEAA Coating on Galvanized Steel		White PVC Coating on Galvanized Steel	
Lab. Sample No.	84-S-50501		84-S-50500		84-S-50500	
Panel No.	84-WM-01 scored	84-WM-02 unscored	84-WM-03 scored	84-WM-04 unscored	84-WM-05 scored	84-WM-06 unscored
Exposure (hours)						
0	-	-	Gloss 73.0	Gloss 83.0	Gloss 25.6	Gloss 33.5
500	No change	No change	Gloss 53.9	Gloss 80.3	No change	Gloss 31.2
1000	No change	No change	slight checking Gloss 25.0	slight checking Gloss 19.8	Gloss 17.5	Gloss 20.9
1500	No change	No change	surface wrinkling Gloss 8.0	surface wrinkling Gloss 13.6	No change	No change
2000	slight brownish surface discolour	slight brownish surface discolour	White spots over surface. Gloss 5.4	Gloss 12.5	Gloss 16.1	No change
2500	No change	No change	White haze over panel surface. Gloss 4.0 Check 4.0	Slight white haze over surface. Gloss 8.1 Check 5.0	Gloss 13.1	No change

Test Reference: ASTM D523 Gloss Rating, D660 Checking

7/ MAINTENANCE OPERATIONS REPORT*

7.1/ Background

The installation of 3.75 km of IBC barrier in the median of Hwy 400 during 1983 required the District to develop a series of new maintenance operations to address the future demands of this new barrier system.

To assist in this development, a trial maintenance operation on a test section of the barrier located in the Downsview Complex was carried on early in 1983. From this experience, it was determined that:

a) A vacuum sewer cleaner could be successfully used for removing the barrier ballast material (stone or sand) in the unfrozen state.

b) A commercially available "Stone Slinger" was the most practical and efficient means of filling the barrier with ballast.

c) All other equipment (other than hand tools) required to repair the IBC barrier were part of the District Maintenance inventory.

7.2/ Field Observations

Following completion of barrier construction in the fall of 1983 no specific maintenance on the IBC barrier was initiated until 84 05 24. On that date, the southbound centre lane was closed in the vicinity of Finch Avenue to:

- inspect the barrier;
- carry out a trial sweeping operation; and
- permit IBC representatives to place a panel overlay repair of a damaged (ripped) section.

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* NOTE: This chapter was prepared by D. Aspinwall of Central Region.

7.2.1/ Inspection

- Many minor hits of the barrier were noted with approximately 50% of the panels affected in some way (refer to Table 8).

- Large amounts of winter sand had accumulated in the paved median adjacent to the barrier over a 2' width.

- Excessive debris accumulation in the catchbasin panels and on the gratings caused blockage of drainage flow (ponding), especially in the spring. A build-up of debris in the barrier cavity due to vehicle updraft was evident.

- Damage to the lower section of the panel from snow plowing operations. This did not cut the metal but removed some of the coating. This resulted from a switch in equipment at the Patrol to a replacement unit which was not equipped with the standard protection device routinely used on snowplows for Highway 400 median work.

7.2.2/ Sweeping

Excessive quantities of materials were present indicating that the cross-section did not tend to self-clean itself to the same extent as the box beam sections.

A standard sweeping operation was initiated, however due to the excessive deposits and the inability to sweep adjacent to the bottom section of the barrier, complete cleaning was not possible. The disturbing of the deposits, however, promoted subsequent self-cleaning of the section.

In general, sweeping was not significantly more difficult than that routinely required. Similar operations, single lane closures and accomplishments can be expected for box beam sections.

7.2.3/ Overlay Installation

The IBC Company's first attempt was unsuccessful due to the conflict of the stone ballast with the securing bolts, and the distortion and internal stresses built up in the damaged section of the barrier. Figures 9 and 10 show an MTC maintenance crew doing a successful panel overlay of a damaged panel section.

7.3/ Repair Procedures

Following extensive analysis of the operations required, a repair operation of several damaged sections of the IBC was initiated on 84 10 17 and 18.

The major components of the repair operation were:
1/ lane closures;
2/ removal and temporary stockpiling of barrier ballast;
3a/ damaged panel removal and replacement;
3b/ realignment of barrier;
4/ refilling barrier with stone ballast;
5/ clean-up of site and removal of lane closures.

1/ Lane Closures

Each inside lane in both the north- and southbound directions had to be closed prior to any operation on the barrier system. These closures provide the necessary safety for employees to work in the median. This requirement results from the roadway section having a narrow median rather than from the barrier itself. Similar lane closures are required for box beam repairs on Hwy 400 to the north.

The lanes were closed utilizing the appropriate procedures contained in the MTC Traffic Control Manual for Roadway Work Operations. Trucks with lane control arrows were required, plus appropriate traffic cone delineation.

2/ Removal of Ballast

The MTC's truck-mounted vacuum was used to empty the barrier compartments of stone (approx. 15 min per panel). The Vactor unit must be emptied after each two panels. This requires transporting the stone to the Patrol Yard where it is dumped and stored for subsequent re-use. This is a repetitive operation and is shown in Figures 12 and 13.

3/ Barrier Repair

The damaged panels were easily unbolted, the barrier realigned and damaged panels replaced. This is a simple, hand operation requiring no specialized equipment (impact wrench). The tools available on the box beam repair truck were generally sufficient for the task.

3b/ Realign Barrier

As a result of an accident impact, as shown in Figure 8, several sections of the barrier were out of line by approximately 250 mm (10"), however they had recieved little individual damage. Consequently, it was decided not to carry out the full repair operations of 2 and 3a above. Instead, the barrier was simply moved back into correct alignment by sliding the barrier with the aid of the Hiab boom of the box beam repair truck.

4/ Refill Barrier with Ballast

A commercially available specialized unit known as a "Stone Slinger" was hired for the refill. Due to its height, a rented loader was required to fill the slinger with the stone removed from the barrier by the vacuum. The stone slinger is ideally suited for filling the barrier while occupying only the single lane closure from operation 1.

5/ Clean-up and Removal of Lane Closures

Very limited clean-up of the site is necessary. Hand sweeping to remove surplus stone ballast is necessary prior to re-opening the lane to traffic.

The above repair operations are generally of a simple routine nature requiring a crew size as follows:

8 employees -- 2 lane closure trucks
1 vacuum truck
1 box beam truck
3 manual workers
1 foreman
plus the rented Stone Slinger and loader operators.

equipment -- 1 truck-mounted vacuum
1 box beam repair truck with Hiab hoist
2 small trucks
1 rented Stone Slinger
1 rented loader

Based upon the experience gained, it would now be possible to complete a total repair operation requiring all the above procedures in one working day -- depending on the extent of damage to the barrier, more than one repair could be achieved in one day.

7.4/ Other Maintenance Issues

In addition to the repair procedures described above, these other maintenance issues should be noted:
a/ Minor damage repairs
b/ Restriction of drainage
c/ Proximity to roadway

a/ Minor Damage -- The repair operations described earlier occurred one year after barrier installation. Only the major damaged locations were addressed, leaving the majority of panels with minor scratches, dents, etc. In the coated barrier section, these minor situations involved damage to the coating system. No repairs to the coating system have yet been initiated by MTC. Undoubtedly this will be necessary to prevent premature deterioration of the barrier, however a relatively quick and simple process is required if positive results are to be achieved.

b/ Restriction of Drainage Flow -- The accumulation of debris in the narrow drainage openings at the catchbasin sites created blockage of the water flow causing ponding onto the roadway surface. This was of particular concern in the freeze/thaw cycles and heavy spring run-off periods.

Also, the limited median shoulder cross-section available for longitudinal flow was easily disrupted by debris, with the result that encroachment onto the driving surface was occurring.

c/ Proximity to Roadway -- The substantial cross-section of the barrier used much of the space available in the limited median width. In the past, limited emergency parking was available adjacent to the box beam barrier (i.e., 4-1/2'), however with the IBC barrier stopped vehicles encroached substantially onto the centre high-speed lane causing a capacity blockage.

7.5/ Costs

Based upon the repairs carried out on 84 10 17 and 18, representing 50% of the damaged sections for one year of life, the annual repair cost of the IBC barrier is estimated at $1760.00 per km.

This figure does not include minor damage touch-up procedures which are estimated at 50% the above, resulting in:

Potential Annual Repair Costs = $2640 per km.

This figure represents an increase of $1190 per km or 79% over the annual repair costs per km of box beam barrier on Hwy 400.

In addition, extra costs have been estimated at $450 per km for the catchbasin clean-out operations. This cost results from the extra manpower and equipment required to remove the barrier covers and the catchbasin grates in the restricted space under the barrier. This operation is shown in Figures 12 and 13 and although there are a number of observers present in these photographs, they give an accurate impression that a large crew of workers is required.

Further unidentified costs will also result from more frequent debris removal from the narrow shoulders and over the catchbasin grates.

7.6/ Conclusions

The maintenance operations required for the IBC barrier do not create major concerns for the District. The work required can be carried out with specialized types of equipment already available in an urbanized maintenance organization. For a rural oriented District, however, the types of operations described earlier in the report would require greater costs due to mobilization of the equipment required.

The performance and maintenance operations associated with the IBC installation on Hwy 400 are considered to result more from the location of the barrier in a narrow 3 m (10') median with centreline drainage flow, than from any requirements directly attributable to the barrier itself.

The comparison to the box beam system to the north is therefore considered the only valid comparison. An analysis on this basis gives an extra maintenance cost of IBC over box beam of $1640 per km year. This figure is based on only one year's experience with estimates of certain potential operations required (e.g., touch-up), and is arrived at by adding $450.00 to $1190.00.